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AUTHOR(S):
SHIGA, MICHIRU; SHIODE, DAISUKE; HU, FUXIANG; TOKAI, TADASHI

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Deep setting of tuna longline hooks using mid-water float system with long float lines to avoid sea turtle bycatch.

MICHIRU SHIGA[1], DAISUKE SHIODE[1], FUXIANG HU[1] & TADASHI TOKAI[1]
1 Department of Marine Biosciences, Tokyo university of Marine Science and Technology
4-5-7 Konan, Minato, Tokyo 108-8477, Japan
E-mail: d051008@kaiyodai.ac.jp

ABSTRACT
Sea turtle bycatch issues are of special concern in tuna longline fisheries. To avoid sea turtle bycatch, we developed a mid-water float system, which is a method of setting the longline hooks at almost the same depth. When enough long float line was deployed with the mid-water float system (the mid-F system), all hooks could be set in water deeper than where sea turtle predominantly forage and in the depth of tuna habitat. Sea trials of full scale longline gear with mid-water float and long float line (long FL) were carried out in the Indian Ocean in December 2005. One mid-water float (buoyancy of 2200gf or 2560gf) was attached to the center of one-basket mainline, both ends of which were hung with two long float lines (100m). The conventional longline setting (the length of float lines were 40m) without any mid-water float was also conducted as a control. The mainline with long float lines were set at a depth from 125m to 175m. The depth range of hooks with mid-F system was at most 50m, while that of the conventional longline setting was over 125.5m. The mid-F & long FL system allowed all hooks to be set at sufficient depth for capture of tuna, with an associated avoidance of sea turtle bycatch as well as more effective tuna catch.

Keywords: bycatch, deep hook setting, mid-water float, sea turtle, tune longline

INTRODUCTION

By-catch of sea turtle is an important issue in tuna longline fisheries. Sea turtles are endangered species, and the effect of sea turtle tuna longline gear on sea turtle bycatch and mortality is a particular concern (Williams *et al.* 1994).

The shape of the mainline in tuna longline gear is a catenary curve (Yoshihara 1951) (Fig. 1 (a)), and therefore the depth of hooks in one basket (a unit of branch lines set on the mainline between the two float lines) varies depending on its connecting point. Polovina *et al.* (2003) reported that loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles usually swim at shallower than 100m, and also that sea turtle bycatch occasionally occurred on hooks set in sallower water. In contrast, tuna species, especially bigeye tuna swim at depths over 200m during daytime (Dagorn *et al.* 2000, Bach *et al.* 2003). In commercial longline fisheries, fishermen use longer mainlines with more hooks and branch lines as one basket to set hooks deeper when targeting bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*).

We focused on the difference in swimming depth between sea turtles and tuna species, and developed a new method for longline setting; the mid-water float system (Shiode *et al.* 2005). A mid water float (mid-F) is a small float attached to a mainline to set all hooks of one basket at almost the same depth. When a sufficiently long float line (long FL) is deployed with the mid-F, all hooks could be set in water deeper than sea turtle habitat (Fig. 1 (b)). Moreover, the mid-F & long FL system allows more hooks to be set in the depth of tuna habitat.

In this paper, we introduce a theoretical equation to obtain the buoyancy required for mid-F to lift the mainline to a given depth. Moreover, we show the result of sea trials using full scale tuna longline gear with the mid-F & long FL, and then confirm the validity of the mid-F system.

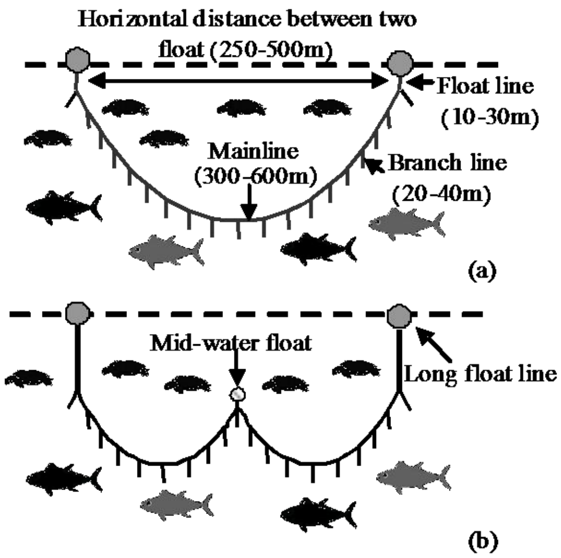

Fig. 1 The shape of tuna longline gear: (a) conventional setting; (b) mid-F with long FL setting

MATERIALS AND METHODS

Longline gear

Sea trials were carried out in the Indian Ocean in December 2005 on a reserch training ship "Umitaka-maru" belonging to Tokyo University of Marine Science and Technology. Twelve branch lines of 35m length were attached to the mainline at intervals of 42m. The length of the float line was 40m in the conventional setting. A single midwater float was attached to the center of one-basket mainline. Mid-F and long FL (100m) setting was deployed in five successive baskets in the middle part of a total of 75 basket. Of the Five baskets for mid-F and long FL setting, the middle one was chosen as experimental basket for measurement of the mainline depth. The mainline depth was also measured in one conventional basket of two baskets away from the five mid-F and long FL baskets. Depth loggers were attached to measure the depth of several joints on the mainline of branch line and float line (Fig. 2). We measured the distance between the two floats of the basket using GPS buoy, and calculated the shortening rate (Fig. 2).Mackerel was used as a bait for all hooks expect for the experimental basket.

The required buoyancy of mid-water float

Required buoyancy F of one mid-water float can be calculated with the following equation;

$$F = [\frac{S_0}{(n+1)} - \frac{h}{2\tanh[L_0/(2(n+1))]}]q + W_b$$

where S_0 is the length of mainline in one basket, n the number of mid-water floats in one basket, h the vertical distance between the lower end of the float line and the mid-water float, L_0 the horizontal distance between the two floats attached to the float line, a_n is a parameter, q weight in water per unit length of mainline with the branch lines, and W_b the weight of one branch line in water, respectively. We tested two mid-water floats; 2560gf and 2200gf buoyancy obtained by the above eqation in sea trials. The former buoyancy was calculated to lift the connecting point of the mid-water float to the depth of connecting point of the 1st and 12th branch lines on the mainline (Fig. 2 (b)), and the latter was caluclated to lift it to those of the 2nd and 11th branch lines (Fig. 2 (c)).

RESULTS

The shapes of each longline setting obtained by measured depths and estimated ones by the catenary curve theory with the shortening rate of the basket are shown in Fig.3. Depths obtained by each logger were averaged over a 10 min period, just before the start of line hauling. The hook depth was calculated by adding the length of branch line to the depth of the connecting point to mainline. In 2560gf mid-F

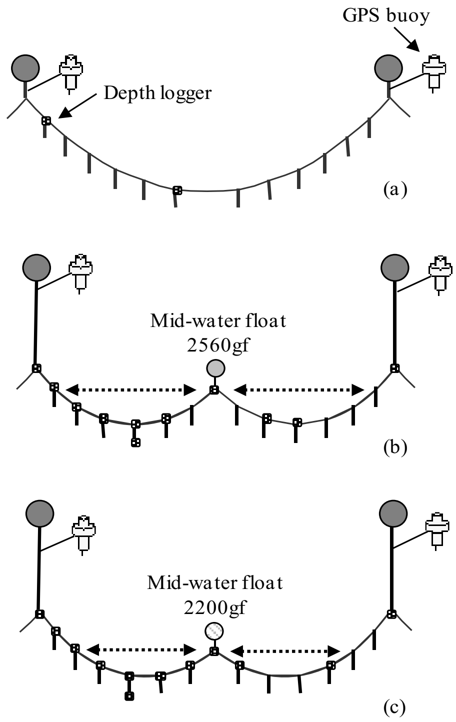

Fig. 2 Longline gear and attachment position of measurement device in sea trials: (a) conventional setting; (b) 2560 gf mid-F setting with long FL; (c) 2200 gf mid-F setting with long FL.

setting, the difference in depth between the connecting points of the mid-water float and the 1st branch line on the mainline was only 0.8m. In 2200gf mid-F setting, the difference in depth between the connecting points of the mid-water float and the 2nd branch line on the mainline was only 3.4m. Thus, in the mid-F & long FL setting, the mid-F connecting point was lifted to the depth level as expected. All hooks were set in water deeper than 100m in the mid-F & long FL setting. Although the depth of hooks was from 108 to 234.4m (depth range: 126.4m) in the coventional setting, it was from 160.6 to 219.4m (depth range: 58.8m) in 2560gf mid-F & long FL setting, and from 164 to 210.1m (depth range: 46.1m) in 2200gf mid-F & long FL setting. In all longline oparations, 47 bigeye tuna were caught in 490 conventional baskets. The depth frequency distribution of hooks catching bigeye tuna in 490 conventional baskets is shown in Fig. 4. Assuming the shape of mainline was a catenary in conventional baskets, the depth of hooks where bigeye tuna were caught was estimated from the position of branch line. Most of the bigeye tuna were caught at over 150m depth, and the mode of distribution was 205m depth. From depth measurement of depth loggers, the depth of hooks were estimated to be 140-280m depth in mid-F & long FL setting, and no hooks were set shallower than 120m depth (Fig. 5).

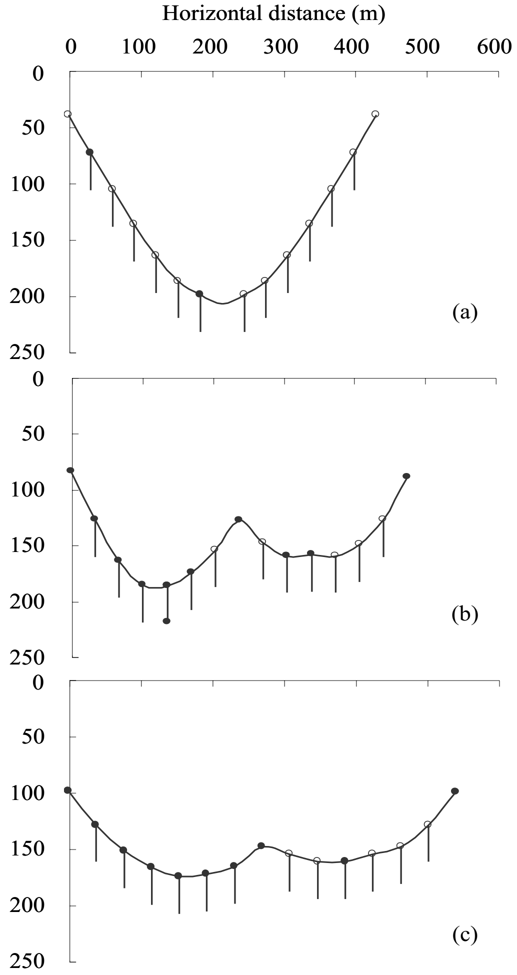

Fig. 3 The shape of experimental basket in sea trials: (a) conventional setting; (b) 2560 gf mid-F setting with long FL; (c) 2200 gf mid-F setting with long FL setting. Small closed circle indicates the position of micro depth logger.

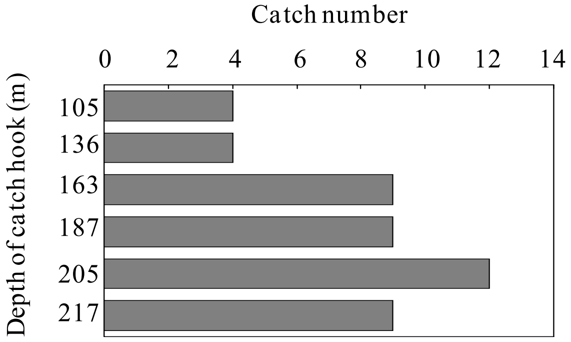

Fig. 4 Depth frequency distribution of hooks catching bigeye tuna in the conventional setting. The number of fish caught by the conventional setting was 47.

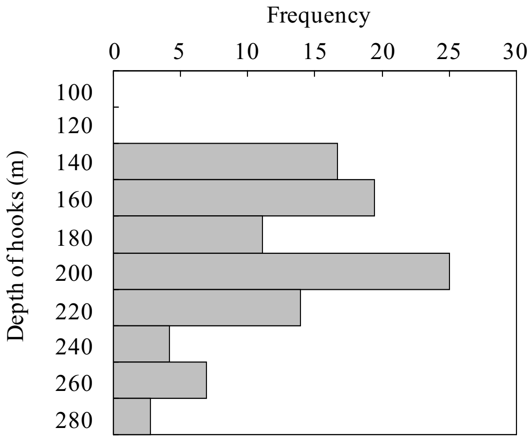

Fig. 5 Hook depth distribution in mid-F with long FL setting. The number of hook attached to the mid-F with long FL setting was 72.

DISCUSSION

The depth range of longline hooks in one basket in the mid-F setting was reduced, compared with the conventional setting. And the long FL allowed all hooks to be set deeper than 150m. This depth range approximately corresponded with the depth where most bigeye tuna were caught in this sea trial.

Using mid-F system with long FL, not only are more longline hooks set sufficiently deep for the tuna habitat, but also no hooks are set in the sea turtle habitat. Moreover, in the longline gear using mid-F system with long FL, the hook depths can be controled by changing the number and buoyancy of mid-water floats.

This system required just small floats and long float lines for one basket. According to the video observation on the deck, mid-water floats could be easily attached to the mainline in a similar way as thebranch line.

In this sea trials, the long FL was set in water without getting entangled, but it may cause some ploblems on the deck during commercial longline operations. However, the mid-F system has some advantages in that less power is needed to haul the longline gear because the mid-F reduced the total weght of the gear in the water, and the number of float lines may be able to be reduced by using mid-water floats instead of several conventional float lines, which allows reduction of labor on the deck.

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